# OROVILLE FERC RELICENSING
## (PROJECT NO. 2100)

## INTERIM REPORT
## SP-F3.2 TASK 2
## SP-F21 TASK 1

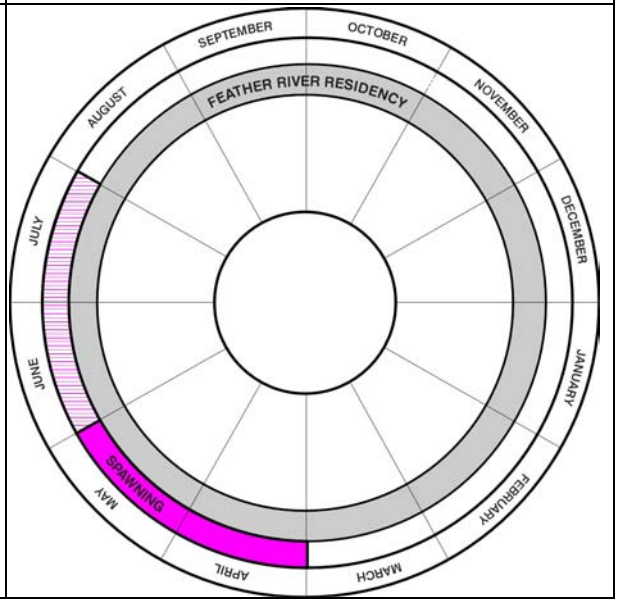
APPENDIX A

***Matrix of Life History and Habitat Requirements for Feather River Fish Species***

**LITERATURE REVIEW OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES**

# PIKEMINNOW

**JANUARY 2003**

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| **General** | | | |
| common name (s) | English name (usually used by fishers and laypeople). | Sacramento squawfish, Sacramento pikeminnow<br><br>The name “pikeminnow” was adopted in 1998 by the American Fisheries Society to replace “squawfish”, which is considered derogatory to Native Americans (Moyle 2002). | |
| scientific name (s) | Latin name (referenced in scientific publications). | *Ptychocheilus grandis* (Ayres) | |
| taxonomy (family) | Common name of the family to which they belong. Also indicate scientific family name. | Minnows – *Cyprinidae* | |
| depiction | Illustration, drawing or photograph. |  |  |

Note: Of the four species of pikeminnows, the northern pikeminnow (*P. oregonensis*) is the most studied. Because the Sacramento pikeminnow appears to be very similar to the northern pikeminnow ecologically, observations on the latter are applicable to Sacramento pikeminnow (Brown et al. 1981).

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| range | Broad geographic distribution, specifying California distribution, as available. | Pikeminnow were historically distributed throughout the Sacramento and San Joaquin river systems (Grant et al. 1999).<br><br>Pikeminnow inhabit low to middle elevation waters in the Sacramento and San Joaquin river basins and are common in tributaries on the western slope of the Sierra Nevada Mountains (Grant et al. 1999).<br><br>Pikeminnow also are found in the Pajaro and Salinas rivers, Russian River, Clear Lake basin, and upper Pit River (Moyle 2002).<br><br>Pikeminnow were introduced into the Eel River in northwestern California in 1980 (Harvey et al. 2002).<br><br>Pikeminnow are found primarily in the Sacramento and San Joaquin river basins, Russian River, and Pajaro-Salinas river drainages of central California (Brown et al. 1981). | |
| native or introduced | If introduced, indicate timing, location, and methods. | Native. | |
| ESA listing status | Following the categories according to California Code of Regulations and the Federal Register, indicate whether: SE = State-listed Endangered; ST =State-listed Threatened; FE = Federally listed Endangered; FT = Federally-listed Threatened; SCE = State Candidate (Endangered); SCT = State candidate (Threatened); FPE = Federally proposed (Endangered); FPT = Federally proposed (Threatened); FPD = Federally proposed (Delisting); the date of listing; or N = not listed. | N (not listed). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| species status | If native, whether: Extinct/extirpated; Threatened or Endangered; Special concern; Watch list; Stable or increasing. If introduced, whether: Extirpated (failed introduction); highly localized; Localized; Widespread and stable; Widespread and expanding. | Native; stable or Increasing (Moyle 2002).<br><br>Pikeminnow are less abundant now, relative to historical population levels, in lowland habitats, where they used to be dominant predators. They have maintained large populations in the Sacramento River, foothill streams, and many regulated streams. Large reservoirs, created by damming Central Valley tributaries, have been colonized by pikeminnow in large numbers. In large hydropower reservoirs, which operate like giant riverine pools and are not drawn annually, large populations of pikeminnow are maintained (Moyle 2002). | |
| economic or recreational value | Indicate whether target species sought for food or trophy. Whether desirable by recreational fishers, commercial fishers, or both. | Pikeminnow have not been commonly used for food by fishermen, although Indian middens contain bones of this species (Wang 1986). | |
| warmwater or coldwater | Warmwater if suitable temperature range is similar to basses; coldwater if suitable temperature range is similar to salmonids. | Warmwater. | |
| pelagic or littoral | Environment: Pelagic - living far from shore; Littoral - living near the shore. | | |
| bottom or water column distribution | Environment: bottom (benthic) or along water column. | Pikeminnow inhabit mid-depth and surface waters (Cooper 1983).<br><br>Pikeminnow normally occupy the middle of the water column in pools and runs (Baltz et al. 1987). | |
| lentic or lotic | Environment: Lentic - pertaining to stagnant water, or lake-like; Lotic - moving water, or river-like. | Pikeminnow are lotic in the Eel River (Brown et al. 1997). | |
| **Adults** | | | |
| life span | Approximate maximum age obtained. | Pikeminnow measuring 26 inches (66 cm) SL from the Russian River have been aged, using opercular bones, at 16 years (Moyle 2002). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | Using scales, pikeminnow have been aged up to 12 years, although this method is considered unreliable for determining the age of older fish (Moyle 2002).<br><br>Pikeminnow can live up to 9 years, and mature in their third or fourth year (in summer) (Wang 1986). | |
| adult length | Indicate: Length at which they first reproduce; average length and maximum length the fish can attain. | Pikeminnow are typically 8.7–9.8 inches (22-25 cm) SL at sexual maturity (Moyle 2002).<br><br>The average length of age 4 pikeminnow harvested in Bear Creek (Colusa County, California) was 10.12 inches (257 mm) SL (Brown 1990).<br><br>The largest reported pikeminnow was 45.3 inches (115 cm) TL (Wang 1986).<br><br>Pikeminnow can potentially be over 3.3 ft (1 m) TL (Moyle 2002).<br>Pikeminnow reach 2.0–3.3 inches (50–85 mm) SL at the end of the first year, 3.9–5.9 inches (100–150 mm) SL at the end of the second year, 6.7–9.8 inches (170–250 mm) SL at the end of the third year, 9.4–10.6 inches (240-270 mm) SL at the end of the fourth year, and 10.2–13.8 inches (260–350 mm) SL at the end of the fifth year (Moyle 2002). | |
| adult weight | Indicate: Weight at which they first reproduce; average weight and maximum weight the fish can attain. | The largest pikeminnow on record weighed 32 lbs. (14.5 kg) (Wang 1986).<br><br>Pikeminnow weigh from 0.25 lb. to 5 lbs. (0.11–2.3 kg) (U.S.Army Corps of Engineers 1990). | |
| physical morphology | General shape of the fish: elongated, fusiform, laterally compressed, etc. | Elongated body, flattened and tapered head, and deeply forked tail. | |
| coloration | Indicate color, and color changes, if any, during reproduction phase. | Large fish are generally a dark brownish- olive on the back and gold-yellow ventrally. Small fish are silvery on all sides with a dark spot at the base of the tail. Fins of breeding adults are tinged with reddish orange (Moyle 2002).<br><br>Several weeks before spawning the Sacramento pikeminnow in Pine Creek developed a dark lateral band (Grant et al. 1999). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| other physical adult descriptors | Unique physical features for easy identification. | Pikeminnow have a large mouth with the maxilla extending behind the front margin of the eye (Moyle 2002). | |
| adult food base | Indicate primary diet components. | Adult pikeminnow feed on juvenile anadromous salmonids (Beamesderfer et al. 1996).<br><br>Pikeminnow larger than 7.9 inches (>200 mm) SL feed primarily on fish, taking other prey such as frogs and crayfish when available (Grant et al. 1999).<br><br>In the Eel River, pikeminnow forage on emigrating juvenile salmon during spring months (Moyle 2002). Sculpin are the most common prey of pikeminnow greater than 9.8 inches (>250 mm) SL in the Eel River (White et al. 2001).<br><br>An Eel River study demonstrated that pikeminnow had a severe negative effect on the abundance of sculpin (White et al. 2001).<br><br>Pikeminnow feed on small salmon, especially those released from hatcheries (Patten et al. 1969). | |
| adult feeding habits | Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder. | Pikeminnow in the Eel River forage at night in runs and shallow riffles to feed on small fish (Moyle 2002).<br><br>A study done in the Columbia River system demonstrated that pikeminnow feed most heavily at dusk and dawn, but full stomachs can be found throughout the day and night (Brown et al. 1981). | |
| adult in-ocean residence time | For anadromous species, age when they migrate to the ocean and duration spent in the ocean before returning to freshwater to spawn. | N/A | |
| adult habitat characteristics in-ocean | For anadromous species, description of the ocean habitat utilized: whether along major current systems, gyres, pelagic (beyond continental shelves) and neritic (above continental shelves) zones, | N/A | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | etc. | | |
| **Adult upstream migration (immigration)** | | | |
| range of adult upstream migration timing | Time of year adults migrate upstream. If applicable, indicate for various runs. | N/A | |
| peak adult upstream migration timing | Time of year most adults migrate upstream. If applicable, indicate for various runs. | N/A | |
| adult upstream migration water temperature tolerance | Range of water temperatures allowing survival. Indicate stressful or lethal levels. | N/A | |
| adult upstream migration water temperature preference | Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental. | N/A | |
| **Adult holding (freshwater residence)** | | | |
| water temperature tolerance for holding adults | Range of water temperatures allowing survival. Indicate stressful or lethal levels. | In the Pit River in Shasta County, pikeminnow were observed in water temperatures of 35.6°F to 68°F (2°–20°C) (Baltz et al. 1987).<br><br>In the Sacramento-San Joaquin river systems, the reported maximum preferred temperature is approximately 78.8°F (26°C). Water temperatures above 100.4°F (38°C) are lethal to pikeminnow (Moyle 2002).<br><br>The reported optimum temperature range for pikeminnow is 61°F–76°F (16.1°C–24.4°C) with an upper lethal water temperature of 85°F (29.4°C) (U.S.Army Corps of Engineers 1990). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| water temperature preference for holding adults | Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental. | | |
| water depth range for holding adults | Reported range of observed (minimum and maximum) water depth utilization. | In the Eel River, pikeminnow were observed at depths of 17.3–45.3 ft (44–115 cm) (Brown et al. 1991).<br><br>In Eel River tributaries, pikeminnow were observed at depths of 3.5–17.7 inches (9 to 45 cm) (Harvey et al. 2002). | |
| water depth preference for holding adults | Reported range of most frequently observed water depth utilization. | In the Eel River, the average water depth in which adult and juvenile pikeminnow were found was 47.2 inches (120 cm) and 18.5 inches (47 cm), respectively. In the Van Duzen River, the average water depth in which adult pikeminnow were found was 45.3 inches (115 cm) in pools and 17.1 inches (45 cm) in combined riffle and run habitats. Juvenile pikeminnow in the Van Duzen River were observed in average water depths of 17.3 inches (44 cm) in pools and 14.2 inches (36 cm) in riffle/run habitats (Brown et al. 1991).<br><br>In the Pit River, pikeminnow were observed in mean water depths of 27.3 to 35.0 inches (69.4–88.8 cm), with mean focal point elevations (i.e., distance above bottom) of 4.9 to 15.5 inches (12.5–39.3 cm) (Baltz et al. 1987).<br><br>Models developed based on habitat use within Eel River tributaries indicate that depth alone explains less than 1% of the variation in age-0 pikeminnow abundance (Harvey et al. 2002). | |
| substrate preference for holding adults | If bottom dwellers, indicate substrate: mud, sand, gravel, boulders, aquatic plant beds, etc. If gravel, indicate range or average size of gravel. | Within the Eel River tributaries, pikeminnow were observed over gravel or finer substrates (Harvey et al. 2002). | |
| water velocity range for holding adults | Reported range of observed (minimum and maximum) water velocity utilization. | Pikeminnow were observed at 0.1–1.01 ft/sec (3–31 cm/sec) in the Eel River (Brown et al. 1991). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | Pikeminnow were observed at mean surface velocities of 0.73–0.91 ft/sec (22.2–27.8 cm/sec) in the Pit River (Baltz et al. 1987). | |
| water velocity preference for holding adults | Reported range of most frequently observed water velocity utilization. | | |
| other habitat characteristics for holding adults | General description of habitat (e.g. turbid or clear waters, lentic or lotic, presence of aquatic plant beds, debris, cover, etc.). | In the Eel River tributaries, pikeminnow utilize large channels with low gradients and warm water temperatures (Harvey et al. 2002).<br><br>Pikeminnow utilize riffles within the Pit River and its tributaries (Cooper 1983).<br><br>A study conducted in the Sacramento-San Joaquin river drainage showed that pikeminnow were uncommon at low elevations, where they once occurred in large numbers, and were most abundant in the larger intermittent and permanent streams at elevations from 656.2–1,640.4 ft (200–500 m) (Moyle et al. 1974). | |
| timing range for adult holding | Time of year (earliest-latest) and duration of stay from upstream migration to spawning. | N/A | |
| timing peak for adult holding | Time of year when maximum number of adults are present before spawning. | N/A | |
| **Spawning** | | | |
| fecundity | Average or range in the number of eggs females lay in a spawning season. | Fecundity in pikeminnow ranges from 15,200 to 21,600 eggs per female (Grant et al. 1999).<br><br>Female pikeminnow between 12.2 to 25.6 inches (31–65 cm) SL contain 15,000 – 40,000 eggs for (Moyle 2002).<br><br>Pikeminnow produce between 5,000 and 20,000 eggs per female (U.S.Army Corps of Engineers 1990). | |
| nest construction | Location and general description of nest -- substrates, aquatic plants, excavations, crevices, habitat types, etc. | Pikeminnow observed in Suisun Creek and Sonoma Creek, usually constructed nests downstream of a pool with running water (Wang 1986). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | Pikeminnow eggs apparently are randomly deposited over gravel beds (American Fisheries Society 2000). | |
| nest size | Size and average dimensions of the nest. | | |
| spawning process | Indicate whether nest builder, broadcast spawner, or other. | Pursued by 1-6 males, the female dips close to the bottom and releases a small quantity of eggs, which are simultaneously fertilized by a male. The fertilized eggs sink to the bottom and adhere to rocks and gravel (observed in Merwin Reservoir) (Moyle 2002). Congregating northern pikeminnow in the lower Columbia River drainage exhibited spawning behavior consisting of “swarming” and “chasing”, which culminated in the spawning act (Patten et al. 1969).<br><br>Observations in the Sacramento-San Joaquin river drainage indicate that pikeminnnow spawn primarily at night (Moyle 2002).<br><br>The spawning process is thought to be similar to that of other native cyprinids and the northern pikeminnow (Moyle 2002). | |
| spawning substrate size/characteristics | Range of substrates used during spawning (e.g. mud, sand, gravel, boulders, beds of aquatic plants). Indicate presence of plant/wood debris, crevices at spawning sites. If gravel, indicate range of average size. | In the Sacramento and San Joaquin river drainages, pikeminnow utilize areas with rocks and gravel (Wang 1986).<br><br>At Merwin Reservoir, the northern pikeminnow spawning area was characterized by steep talus slopes of shale rocks [5.9–7.9 inches (15 to 20 cm) in diameter] (Patten et al. 1969).<br><br>Northern pikeminnow in Idaho lakes were observed spawning over rocks 2.0 to 9.8 inches (5 to 25 cm) in diameter (Patten et al. 1969). | |
| preferred spawning substrate | Indicate preferred spawning substrate (e.g. mud, sand, gravel, boulders, plant bed, etc). | Within the Sacramento River system, the preferred spawning substrate(s) habitat are gravel riffles or shallow flowing areas at the base of the pools (Moyle 2002). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | In the Sacramento-San Joaquin river system, pikeminnow spawning was observed in gravel riffles (Wang 1986). | |
| water temperature tolerance for spawning | Range of water temperatures allowing survival. Indicate stressful or lethal levels. | In the Sacramento-San Joaquin river systems, the reported maximum preferred temperature is approximately 78.8°F (26°C). Water temperatures above 100.4°F (38°C) are lethal to pikeminnow (Moyle 2002).<br><br>The reported upper lethal water temperature for pikeminnow is 85°F (29.4°C) (U.S.Army Corps of Engineers 1990). | |
| water temperature preference for spawning | Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation. | Pikeminnow spawning was observed at water temperatures of 56°F to 62.6°F (13.3°C to 17°C) within the Eel River drainage (Harvey et al. 2002).<br><br>Pikeminnow in Pine Creek were observed spawning in water temperatures of 53.6°F to 68°F (12°C to 20°C) (Grant et al. 1999).<br><br>Males typically arrive to spawning areas when water temperatures reach 59°F – 68°F (before female arrival) (15°C–20°C) (Moyle 2002).<br><br>Pikeminnow were observed spawning in water temperatures greater than 57.2°F (>14°C) in tributaries of the Sacramento-San Joaquin River system (Wang 1986).<br><br>The average water temperature during pikeminnow spawning in Merwin Reservoir was 62.5°F (17°C) (Patten et al. 1969).<br><br>Pikeminnow reproduced in the largest, warmest tributaries within the Eel River drainage (Harvey et al. 2002). | |
| water velocity range for spawning | Minimum and maximum speed of water current the spawning fish can tolerate. | | |
| water velocity preference for spawning | Preferred water current (flow velocity) during spawning. | Pikeminnow spawn in gravel riffles or shallow flowing areas at the base of pools (Moyle 2002). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | Calm water conditions prevailed during the period of pikeminnow spawning in Merwin Reservoir (Patten et al. 1969).<br><br>Within the Monticello Reservoir basin, Sacramento pikeminnow in streams were reported to migrate upstream for spawning during high flows (Grant et al. 1999). | |
| water depth range for spawning | Reported range of observed (minimum and maximum) water depth utilization. | Within Merwin Reservoir, spawning occurred at a depth below 1.2 inches (3 cm), and the maximum depth was determined by the thermocline (Patten et al. 1969). | |
| water depth preference for spawning | Reported range of most frequently observed water depth utilization. | Pikeminnow were observed spawning in Merwin Reservoir at a depth range of 3.0–7.9 inches (5 cm to 20 cm) (Patten et al. 1969).<br><br>Pikeminnow spawn in gravel riffles or shallow flowing areas at the base of pools (Moyle 2002). | |
| range for spawning timing | Earliest and latest time of season or year in which spawning occurs. | In the Eel River drainage, spawning occurs from May through June (Harvey et al. 2002).<br><br>In the Sacramento-San Joaquin river system, spawning occurs from April through July (Wang 1986).<br><br>In Pine Creek, spawning occurred between mid-April and early May (Grant et al. 1999). | |
| peak spawning timing | Time of year most fish start to spawn. | Fecund fish move to spawning areas during April and May (Moyle 2002).<br><br>In Pine Creek, most spawning occurred by May 3 (Grant et al. 1999).<br><br>In Merwin Reservoir, northern pikeminnow spawning extended through June and July, but was most active during the first part of July (Wang 1986). | |
| spawning frequency (iteroparous/semelparous) | Semelparous - producing all offspring at one time, such as in most salmon. Usually these fish die after reproduction. Iteroparous - producing offspring in successive, e.g., annual or seasonal batches, as is the case in most fishes. | Iteroparous. Pikeminnow spawn annually, but only when conditions are favorable (Moyle 2002). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| **Incubation/early development** | | | |
| egg characteristics | Shape, size, color, in clusters or individuals, stickiness, and other physical attributes. | Mature eggs are adhesive and spherical, measuring 0.86–0.94 inches (22–24 mm) in diameter (Wang 1986). | |
| water temperature tolerance for incubation | Range of water temperatures allowing survival. Indicate stressful or lethal levels. | | |
| water temperature preference for incubation | Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation. | Northern pikeminnow eggs will hatch when reared at 64.4°F (18°C); suitable water temperatures are likely to be similar for Sacramento pikeminnow (Moyle 2002).<br><br>Northern pikeminnow eggs are incubated under laboratory conditions at water temperatures of 59°F–62.6°F (15°C to 17°C) (Gadomski et al. 2001). | |
| time required for incubation | Time duration from fertilization to hatching. Note: Indicate at which temperature range. Incubation time is temperature-dependent. | Northern pikeminnow eggs hatch in 4-7 days at 64.4°F (18°C). Fry begin shoaling in another 7 days (Moyle 2002).<br><br>Laboratory reared northern pikeminnow eggs have been reported to hatch in 8-10 days at 59°F–62.6°F (15°C to 17°C) (Gadomski et al. 2001).<br><br>Pikeminnow eggs are reported to hatch in 7 days at 65°F (18.3°C) (U.S.Army Corps of Engineers 1990). | |
| size of newly hatched larvae | Average size of newly hatched larvae. | Pikeminnow larvae range from 0.38 to 0.5 inches (9.7–12.5 mm) TL (Wang 1986). | |
| time newly hatched larvae remain in gravel | Time of year of hatching, and duration between hatching and emergence from gravel. | Newly hatched larvae remain in crevices of the nesting area for a short period until the yolk sac is absorbed (Wang 1986). | |
| other characteristics of larvae | Alevin -- early life history phase just after hatching (larva) when yolk-sac still present. | | |
| timing range for emergence | Time of year (earliest-latest) hatchlings (larvae and alevins) leave or emerge from the nesting/hatching (gravel) sites. | | |
| timing peak for emergence | Time of year most hatchlings emerge. | | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| size at emergence from gravel | Average size of hatchlings at time of emergence. | At the completion of the yolk-sac stage, Sacramento pikeminnow are from 0.33 to 0.35 inches (8.5–9 mm) (Wang 1986). | |
| **Juvenile rearing** | | | |
| general rearing habitat and strategies | General description of freshwater environment and rearing behavior. | Soon after spawning occurs, shoals of larvae or post-larvae can be observed in shallow pool edges or backwaters, often in association with larvae of other native fishes. As the small fish become more active swimmers, they enter deeper water, especially in runs and along riffles associated with cover. Juvenile pikeminnow can disperse widely in their first year of life, colonizing stream reaches that have been dried up by drought or made available to them through introductions. Young-of-year typically disperse downstream, whereas yearlings are more likely to move upstream (Moyle 2002). | |
| water temperature tolerance for juvenile rearing | Range of water temperatures allowing survival. Indicate stressful or lethal levels. | Juvenile pikeminnow in Eel River tributaries were sampled at maximum weekly average water temperatures of 63.9°F–76.1°F (17.7°C–24.5°C) (Harvey et al. 2002). | |
| water temperature preference for juvenile rearing | Range of suitable, preferred, or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation. | Age-0 pikeminnow were particularly abundant in the warmest tributaries to the Eel River (Harvey et al. 2002). | |
| water velocity ranges for rearing juveniles | Reported range of observed (minimum and maximum) water velocity utilization. | Juvenile pikeminnow were observed in mean water column velocities of 0.36 ft/sec (11 cm/sec) and 0.03–0.33 ft/sec (1–10 cm/sec) within the Van Duzen River (Brown et al. 1991).<br><br>Juvenile pikeminnow were observed in flows of 0.35–9.5 cfs (0.01–0.27 $m^3$/sec) in Eel River tributaries (Harvey et al. 2002). | |
| water velocities preferred by rearing juveniles | Reported range of most frequently observed water velocity utilization. | | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| water depth range for juvenile rearing | Reported range of observed (minimum and maximum) water depth utilization. | | |
| water depth preference for juvenile rearing | Reported range of most frequently observed water depth utilization. | Mean water depths in Eel River tributaries, where juvenile pikeminnow were sampled, ranged from 3.45 to 17.7 inches (9–45 cm) and averaged 11 inches (28 cm) (Harvey et al. 2002). | |
| cover preferences for rearing juveniles | Type of cover for protection from predators used by rearing juveniles (e.g. crevices, submerged aquatic vegetation, overhanging vegetation, substrate cover, undercover bank, small woody debris, large woody debris). | Juveniles were observed most often using pools in the Van Duzen River (Brown et al. 1991).<br><br>Various studies have shown that cyprinid larvae prefer shallow, low velocity, vegetated habitats (Gadomski et al. 2001).<br><br>Wetted areas of Eel River tributaries provided cover for juvenile pikeminnow (Harvey et al. 2002). | |
| food base of juveniles | Indicate primary diet components. Also indicate the diet changes, if any, as growth occurs. | In the lower American River, in which flows are regulated, juvenile pikeminnow feed on small aquatic insects, especially corixids (water boatmen) and chironomid midge larvae; they also feed on larval suckers when they are abundant (Moyle 2002).<br><br>Pikeminnow under 3.9 inches (10 cm) SL feed on aquatic insects, switching to fish and crayfish between 3.9 and 7.9 inches (10 and 20 cm) SL (Moyle 2002).<br><br>In tributaries, juveniles take insect larvae, small insects, small minnows, and salmonid juveniles. Estuarine juveniles feed on small striped bass and splittail, in addition to crustaceans (Wang 1986). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| feeding habits of rearing juveniles | Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder. Also indicate change of feeding habits growth occurs. | As observed in the Sacramento River system, juvenile pikeminnow forage actively during the day, with peak feeding occurring in the early morning (Moyle 2002).<br><br>Pikeminnow are opportunists, taking prey on the bottom, at the surface, or in between, depending on type, abundance, and time of day (Moyle 2002). | |
| predation of juveniles | Indicate which species prey on juveniles. | Juvenile pikeminnow are prey of herons in shallow water and other fish species in deeper water (Moyle 2002). | |
| timing range for juvenile rearing | Range of time of year (months) during which rearing occurs. | Studies within the San Joaquin River drainage showed that juveniles inhabited streams until October or November, then migrated into deeper portions of large water bodies (Wang 1986).<br><br>Juveniles may enter Eel River tributaries most frequently in late summer (May-June) (Harvey et al. 2002). | |
| timing peak for juvenile rearing | Time of year (months) during which most rearing occurs. | N/A | |
| **Juvenile emigration** | | | |
| time spent in fresh water prior to emigrating | Duration (in years and/or months) from emergence to emigration to the ocean. | N/A | |
| water temperature tolerances during emigration | Range of water temperatures allowing survival. Indicate stressful or lethal levels. | N/A | |
| water temperature preferences during emigration | Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation. | N/A | |
| emigration timing range | Time of year juveniles commence emigration and duration of emigration. | N/A | |
| emigration timing peak | Time of year most juveniles are emigrating. | N/A | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| size range of juveniles during emigration | Minimum and maximum sizes (inches or mm) of emigrating juveniles. Indicate average size. | N/A | |
| factors associated with emigration | Pulse flows, water temperature changes, turbidity levels, photoperiod, etc. | N/A | |
| **Other potential factors** | | | |
| DO | Levels of DO in water expressed in mg/L tolerated by fish. | . | |
| pH | Alkalinity/acidity of water (expressed in pH) that fish can tolerate. | | |
| turbidity | Indicate turbidity or state of water (e.g., clear water or presence of siltation or organic/inorganic matter in water) that fish can tolerate. | Pikeminnow are largely absent from highly turbid habitats (Moyle 2002). | |
| factors contributing to mortality | e.g. fishing/angling mortality, drastic habitat alterations, unfavorable climatic changes, etc. | Factors affecting pikeminnow populations include the introduction of nonnative species (competitors) and alteration of river systems (e.g., construction of dams and reduced stream flows due to diversions) (Grant et al. 1999). | |
| **Predation-related characteristics** | | | |
| consumption rates by size | Rate of consumption of prey by predator size. | | |
| consumption rates by lifestage | Rate of consumption of prey by predator lifestage. | Consumption of juvenile salmonids by northern pikeminnow was measured at two locations in the Columbia River system. In the McNary Dam tailrace, consumption rates between April and August of 1983 through 1988 were 0.139-2.027/prey/predator/day, and in the John Day Reservoir pool, consumption rates were 0.043-0.251 prey/predator/day (Vigg et al. 1991).<br><br>At John Day Reservoir the daily consumption ratio for northern pikeminnow over 17.76 inches (451 mm FL) is greater than 13.2 mg consumption prey/g predator/day | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | Salmonids compose an increasing proportion of the total ratio as the pikeminnow grows (Vigg et al. 1991). Consumption rates of northern pikeminnow in the Columbia River system near dams follow classical functional response models – increasing consumption rates with increasing prey densities up to satiation levels (Northwest Fisheries Science Center 2000). | |
| consumption rates by water temperature | Rate of consumption of prey by water temperature. | Northern pikeminnow have rapid digestion rates. Fish held in cages in their natural habitats (in Griffen and Cultus lakes) digested fish at a rate of 14%/hr at temperatures 50°F–53.6°F (10°C–12°C). Digestive rates increased with increasing temperatures. In water temperatures of 39.2°F–42.8°F (4°C–6°C) digestion rates were 5%/hr and at 75.2°F (24°C) digestion rates were 40-50%/hr. These results indicate that at higher temperatures, pikeminnow feed more heavily and frequently (Brown et al. 1981).<br><br>In the Columbia River system, the highest pikeminnow consumption rates occurred in July, concurrent with maximum water temperatures and maximum abundance of juvenile salmon (Vigg et al. 1991). | |
| growth rate | Rate at which growth occurs. | Growth rates tend to be lowest in small streams and fastest in large, warm rivers. Growth rates in the lower Sacramento River are 1.2-1.5 times higher than growth rates elsewhere (Moyle 2002). | |
| community interactions (predators) | Known predators. | Juvenile pikeminnow are prey of herons in shallow water and other fish species in deeper water (Moyle 2002). | |
| community interactions (prey) | Known prey. | Pikeminnow are known to feed on:<br><br>▪ small aquatic insects<br>▪ corixids<br>▪ chironomid midge larvae<br>▪ crayfish<br>▪ smaller pikeminnow<br>▪ lamprey ammocoetes<br>▪ California roach<br>▪ Sacramento sucker<br>▪ rainbow trout<br>▪ threespine stickleback | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | ▪ Chinook salmon<br>▪ sculpin (Moyle 2002). | |
| community interactions (competitors) | Known competitors. | Salmonids. Pikeminnow have gained a reputation in the western United States as both predators and competitors of salmon and trout. However, through an examination of the available literature, it was concluded that there was little evidence of an impact of pikeminnow predation on the number of returning salmon. Pikeminnow do not appear to be significant predators of salmon and trout except under highly localized or unusual circumstances, such as dams and diversions that create habitat more favorable to pikeminnow, and poorly planned releases of hatchery smolts (Brown et al. 1981). Survival of salmonids is weakly affected by changes in pikeminnow distribution, changes in pikeminnow consumption rate near the upstream dam (McNary Dam), residence time, or flow (Beamesderfer et al. 1990). | |
| predator diet by size | Diet of fish by size classes. | In the Central Valley, pikeminnow are at the top of the aquatic food chain. Pikeminnow under 3.9 inches (10 cm) SL feed predominantly on aquatic insects. At 3.9–7.9 inches (10–20 cm) SL, they switch to fish and crayfish (Moyle 2002).<br><br>Based on laboratory studies using northern pikeminnow from the Columbia River, a pikeminnow consumption model was developed. This model predicts that a 300-349 mm FL northern pikeminnow could eat seven to eight 0.25–0.28 ounces (7-8 g) meals per day at 50°F (10°C), whereas models derived from previous laboratory studies would predict that the same fish would consume less than one 0.28 ounce (8 g) meal per day (Beyer et al. 1988).<br><br>In the Eel River, large pikeminnow prey on lamprey ammocoetes (Moyle 2002).<br><br>In free-flowing sections of the Willamete River in Oregon, 75% of pikeminnow over 11.8 inches (30 cm) FL prey on salmonids during outmigration, indicating that only a portion of the population may pose a threat to salmonids (Brown et al. 1981). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| | | Large pikeminnow are documented to prey on California roach, Sacramento sucker and rainbow trout (Moyle 2002).<br><br>In Bear Creek, smaller pikeminnow as a group consumed a wider variety of items than larger pikeminnow, but individuals tended to consume only one or two food types at a particular time (Brown 1990).<br><br>In the Eel River and below Red Bluff Diversion Dam on the Sacramento River, large pikeminnow forage on outmigrating juvenile salmonids during spring (Moyle 2002).<br><br>For northern pikeminnow 7.1 inches (18 cm) FL, fish and crayfish account for more than 50% of their diet. In the Columbia River, fish and crayfish become an important component of the diet for pikeminnow 9.1–9.8 inches (23–25 cm) FL. (Brown et al. 1981). | |
| predator diet by age group | Diet of fish by age group. | In the lower American River, juvenile pikeminnow feed on small aquatic insects, corixids, chironomid midge larvae, and larval suckers. Fish larger than 7.9 inches (20 cm) SL feed exclusively on fish and crayfish. In smaller streams, they cannibalize younger pikeminnow (Moyle 2002). | |
| association of predators to physical facilities including habitat conditions created by operations | Habitat conditions created by operations that are conducive to predation (velocities, temperatures). | At Red Bluff Diversion Dam, nighttime predation rates of pikeminnow were enhanced when lights on the dam were turned on, apparently making prey more visible (Moyle 2002). | |
| association of predators to physical facilities including instream flow obstructions/diversions | Instream flow obstructions and/or diversions associated with structures and facilities that are conducive to predation. | In large hydropower reservoirs, which behave like giant riverine pools and are not drawn down annually, large populations of pikeminnow are maintained (Moyle 2002). | |

| Element | Element Descriptor | General | Feather River specific |
|---|---|---|---|
| association of predators to physical facilities including unusual flow and/or water temperature patterns | Flow or water temperature associated with structures, or operations facilities that are conducive to predation. | At Red Bluff Diversion Dam, heavy predation on salmon occurs when dam gates are closed, aggregating pikeminnow and confusing or injuring small salmon in turbulent flows (Brown et al. 1981; Moyle 2002).<br><br>Habitat alterations, such as channelization, removal of riparian vegetation, and impoundments, tend to raise water temperatures and lower dissolved oxygen levels, creating conditions more likely to favor pikeminnow than salmonids (Brown et al. 1981).<br><br>High flows and increased turbidity decrease pikeminnow predation rates on migrating smolts (Brown et al. 1981).<br><br>In the Columbia River system, the predation rate of northern pikeminnow on salmonids is higher in specific locations such as dams, forebays, and tailraces than in pools (Northwest Fisheries Science Center 2000)<br><br>In high velocity, free-flowing water in the Columbia River system, the pikeminnow switches its diet to benthic prey (Tabor et al. 1993). | |

References

American Fisheries Society. American Fisheries Society, Idaho Chapter; Northern Pikeminnow. Available at http://www.fisheries.org/idaho/northern_pikeminnow.htm.

Baltz, D. M., B. Vondracek, L. R. Brown, and P. B. Molye. 1987. Influence of Temperature on Microhabitat Choice by Fishes in a California Stream. Transactions of the American Fisheries Society 116:12-20.

Beamesderfer, R. C., B. E. Rieman, L. J. Bledsoe, and S. Vigg. 1990. Management Implications of a Model of Predation by a Resident Fish on Juvenile Salmonids Migrating Through a Columbia River Reservoir. North American Journal of Fisheries Management 10:290-304.

Beamesderfer, R. C. P., D. L. Ward, and A. A. Nigro. 1996. Evaluation of the Biological Basis for a Predator Control Program on Northern Squawfish (*Ptychocheilus oregonensis*). Canadian Journal of Fisheries and Aquatic Science 53:2898-2908.

Beyer, J. M., G. Lucchetti, and G. Gray. 1988. Digestive Tract Evacuation in Northern Squawfish (*Ptychocheilus oregonensis*). Canadian Journal of Fisheries and Aquatic Science 45:548-553.

Brown, L. R. and P. B. Molye. 1981. The Impact of Squawfish on Salmonid Populations: a Review. North American Journal of Fisheries Management 1:104-111.

Brown, L. R. 1990. Age, Growth, Feeding, and Behavior of Sacramento Squawfish (*Ptychocheilus grandis*) in Bear Creek, Colusa Co., California. The Southwestern Naturalist 35:249-260.

Brown, L. R. and P. B. Moyle. 1991. Changes in Habitat and Microhabitat Partitioning Within an Assemblage of Stream Fishes in Response to Predation by Sacramento Squawfish (*Ptychochelius grandis)*. Canadian Journal of Fisheries and Aquatic Science 48:849-856.

Brown, L. R. and P. B. Moyle. 1997. Invading Species in the Eel River, California: Successes, Failures, and Relationships With Resident Species. Environmental Biology of Fishes 49:271-291.

Cech Jr., J. J., S. J. Mitchell, D. T. Castleberry, and M. McEnroe. 1990. Distribution of California Stream Fishes: Influence of Environmental Temperature and Hypoxia. Environmental Biology of Fishes 29:95-105.

Cooper, J. J. 1983. Distributional Ecology of Native and Introduced Fishes of the Pit River System, Northeastern California, With Notes on the Modoc Sucker. Calif.Fish and Game 69:39-53.

Gadomski, D. M., C. A. Barfoot, J. M. Bayer, and T. P. Poe. 2001. Early Life Histroy of Northern Pikeminnow in the Lower Columbia River Basin. Transactions of the American Fisheries Society 130:250-262.

Grant, G. C. and P. E. Maslin. 1999. Movements and Reproduction of Hardhead and Sacramento Squawfish in a Small California Stream. The Southwestern Naturalist 44:296-310.

Harvey, B. C., J. L. White, and R. J. Nakamoto. 2002. Habitat Relationships and Larval Drift of Native and Nonindigenous Fishes in Neighboring Tributaries of a Coastal California River. Transactions of the American Fisheries Society 131:159-170.

Moyle, P. B. 2002. Minnows, Cyprinidae - Sacramento Pikeminnow, (*Ptychocheilus grandis*) *in* Inland Fishes of California. Los Angeles, California: University of California Press, 154-158.

Moyle, P. B. and R. D. Nichols. 1974. Decline of the Native Fish Fauna of the Sierra Nevada Foothills, Central California. American Midland Naturalist 92:72-83.

Northwest Fisheries Science Center. 2000. Predation on Salmonids Relative to the Federal Columbia River Power System. White Paper. Seattle, Washington: Northwest Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

Patten, B. G. and D. T. Rodman. 1969. Reproductive Behavior of Northern Squawfish, *Ptychocheilus oregonensis*. Transactions of the American Fisheries Society 98:108-111.

Steigenberger, L. W. and P. A. Larkin. 1974. Feeding Activity and Rates of Digestion of Northern Squawfish (*Ptychocheilus oregonenis*). Canadian Journal of Fisheries and Aquatic Science 31:411-420.

Tabor, R. A., R. S. Shively, and T. P. Poe. 1993. Predation on Juvenile Salmonids by Smallmouth Bass and Northern Squawfish in the Columbia River Near Richland, Washington. North American Journal of Fisheries Management 13:831-838.

U.S.Army Corps of Engineers. 1990. Fisheries Handbook of Engineering Requirements and Biological Criteria. Portland, Oregon: Fish Passage Development and Evaluation Program.

Vigg, S., T. P. Poe, L. A. Prendergast, and H. C. Hansel. 1991. Rates of Consumption of Juvenile Salmonids and Alternative Prey Fish by Northern Squawfish, Walleyes, Smallmouth Bass, and Channel Catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. Report # Technical Report 9.

White, J. L. and B. C. Harvey. 2001. Effects of an Introduced Piscivorous Fish on Native Benthic Fishes in a Coastal River. Freshwater Biology 46:987-995.